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USERS' MANUAL

INCLINOMETER CASING INSTALLATION FOR SUBSURFACE MONITORING OF LATERAL MOVEMENT AND SETTLEMENT

MODEL EAN-AT series



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1 INTRODUCTION

Inclinometer casing (also called ABS grooved access casing) play a vital role in measurement of lateral deformation (inclination) and vertical displacement (settlement/heave). For this purpose, series of inclinometer casing (with standard 3 m length), attached to each other, are installed in a borehole or embedded in earth/rock fill or concrete structure during construction or fixed to the vertical face of a completed structure. Any subsurface or structural movement may result in a displacement of the casing. Encardio-rite offers the following precision instruments to monitor the casing displacement:

- Encardio-rite model EAN-26M digital inclinometer system for manual monitoring of lateral displacement
- Encardio-rite model EAN-52M in-place inclinometer system (**IPI**) for online web base monitoring of lateral movement
- Encardio-rite model EDS-91/2.1 Magnetic settlement probe with datum/spider magnets installed outside the casing at various depths, for manual monitoring of settlement.
- Encardio-rite model EAN-61MS In-place 3D inclinometer system (**IPIS**) for online web base monitoring of lateral movement and settlement.

These monitoring systems are described in brief in the next section.

The access casings are installed with fixed couplings where no significant or a little settlement is anticipated (e.g. in d-walls). Where substantial settlement is expected, the casing maybe installed with telescopic couplings and suitable magnetic rings for settlement measurements (e.g.in earth fill embankments).

If casing is installed in a landslide area to monitor unstable slopes, it is recommended that the casing is installed deep enough into stable rock (passing through the expected zone of movement). Also, it is recommended to use a larger diameter inclinometer casing (80 mm) as large movements are expected at such locations. Please refer to Appendix 1 on 'Importance of internal diameter of casing, for a better understanding.

The sturdy Encardio-rite ABS (Acrylonitrile Butadiene Styrene) casing has four longitudinal keyway grooves oriented at 90° to each other, specially produced to close tolerances. The grooves act as an access guide for tilt sensor wheels, which can run smoothly inside these keyways.

1.1 How to use this manual

The manual is divided into a number of sections. Each section contains a specific type of information. Refer to the index for any specific information required.

To make this manual more useful, your valuable comments and suggestions are invited regarding any additions or enhancement. You are also requested to please point out any errors that are found while going through the manual.

1.2 Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users' attention.

1.3 General information

This users' manual is intended to provide sufficient information for installing and making optimum use of ABS inclinometer casing. The manual also contains instructions on how to set-up for lowering of the measuring instruments into the gage well for purpose of taking inclination/settlement readings.

NOTE: Installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on the installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However, the best of instruction manuals cannot provide for each and every condition in the field, which may affect performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

This equipment should be installed, maintained and operated by qualified personnel. Any errors or omissions in installation, data or data interpretation are not the responsibility of Encardio-rite Electronics Pvt. Ltd. or its Group Companies

1.4 Mandatory checks after installation of inclinometer casing

Logically, these checks should have been given later on in the manual after procedure of installation of casing is described. They are included in the first chapter only to emphasize that they should never be missed. Please read section 1.4 once again after the installation of the casing is complete.

1.4.1 With Encardio-rite model EAN-26 DP dummy probe

Lower dummy probe inside the inclinometer casing, first in grooves in one direction and then in the perpendicular direction to verify that the grooves are smooth with no concrete or foreign material stuck in them. Clean if necessary.

The monitoring instruments described in the introduction should never be lowered down in the gage well unless the latter is checked by the dummy probe. The monitoring instrument may get stuck in the gage well and you may permanently lose it in case this instruction is not followed.

NOTE: The model EAN-26DP dummy probe is not a part of the supply and has to be ordered separately.

1.4.2 With Encardio-rite model EAN-26M inclinometer probe

In case an **IPI** or **IPIS** system is used to monitor the gage well, always ensure to take initial reading of x-y profile of borehole with model EAN-26M inclinometer probe and store the data for future reference. This step is very important and should never be ignored.

The inclinometer probe gives the true x-y profile of the borewell with a gage length of 0.5 m. In case future readings are taken manually with the EAN-26M inclinometer probe, these readings form the initial reference with respect to which all future readings are compared. In case any abnormal movement is observed later on when **IPI** or **IPIS** is installed in the borehole, the borehole profile can be verified by removing the **IPI** or **IPIS** and taking a fresh set of readings with the model EAN-26M inclinometer probe.

NOTE: The model EAN-26M inclinometer probe is not a part of the supply (with **IPI** or **IPIS** systems) and has to be ordered separately.

CAUTION: The initial x-y profile taken with the model EAN-26M inclinometer probe is a reference for future use. It should be carefully stored and never be lost till the gage well is used for monitoring.

1.4.3 X-Y coordinates with Prism target

Determine initial Northing (X) and Easting (Y) positions of casing top by surveying after the casing is set. For this purpose, Encardio-rite provides different types of prism assembly as described below. Readings should be taken with an accurate and precise total station. This data should be treated as a reference during verification of deflection at a later date.

1.4.3.1 For digital inclinometer

An aluminium adaptor (suitable for inclinometer casing EAN-AT-70) with holder pin is available to mount the ERT-10P2 prism target (figure 1-1).

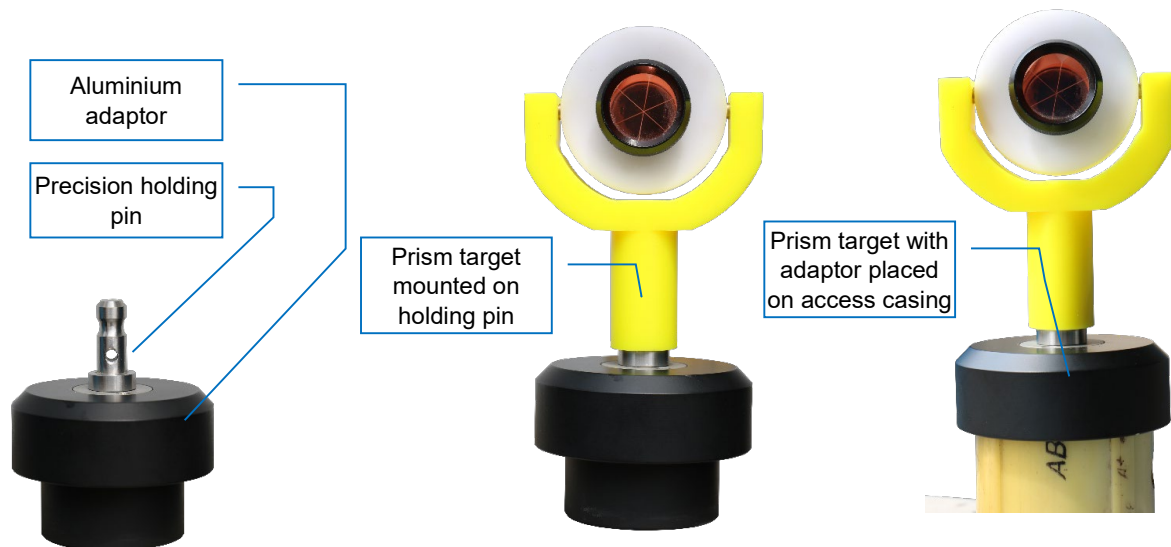


Figure 1-1 Prism adapter for inclinometer casing suitable for model EAN-26M digital inclinometer system

1.4.3.2 For IPI or IPIS

In case the inclinometer casing is used for **IPI** or **IPIS** systems, ERT-10P2 prism target can be directly mounted on the suspension bracket (which is an integral part of the **IPI** or **IPIS**), with a precision prism holding pin adaptor, as shown in figure 1-2.

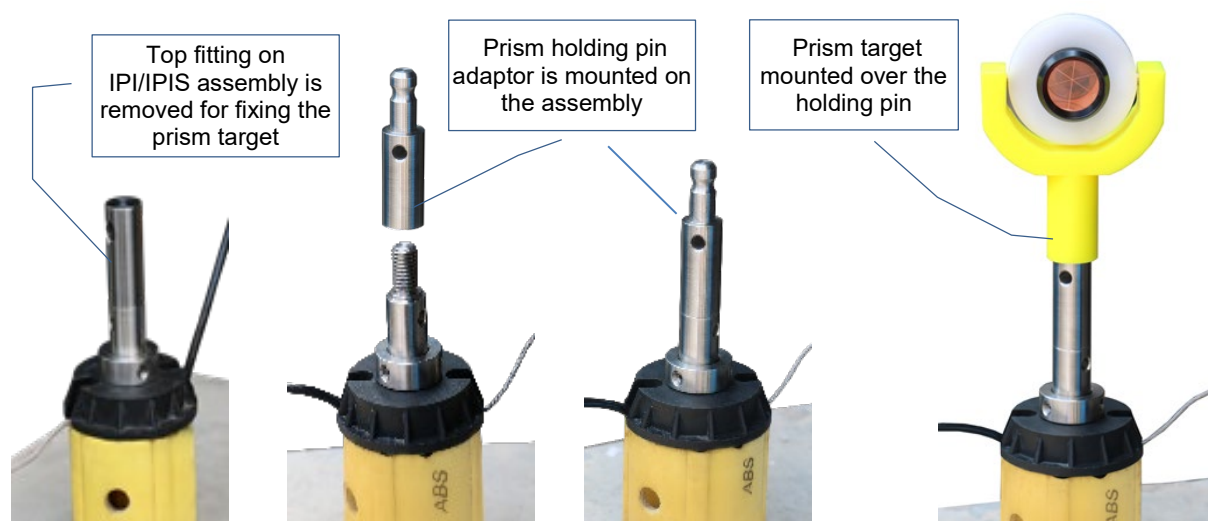


Figure 1-2 Prism target mounting accessories suitable for model EAN-52M IPI & EAN-61MS 3D IPIS systems

1.4.4 Elevation by settlement point

Additionally, determine the elevation of the pipe top using a precision digital level. For this purpose a settlement survey marker should be mounted adjacent to top of inclinometer casing that will serve as survey reference point. The survey marker is illustrated in figure 1-3.

This will allow inclinometer as well as settlement profile to be referenced to an absolute reference (elevation above sea level) should datum reference at the bottom be required to be verified due to any reason.

NOTE: The aluminium adaptor with holder pin, prism holding pin adaptor, prism target ERT-10P2 or the settlement point are not a part of the supply and have to be ordered separately.

CAUTION: The Northing (X), Easting (Y) and Elevation (Z) of the casing top taken by the precision total station and digital level is a reference for future use. It should be carefully stored and never be lost till the borewell is used for monitoring.



Figure 1-3 Survey target to be mounted on top concrete platform to determine elevation of casing top

1.4.5 With Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe

In case settlement is to be monitored, manually using the EDS-91/2.1 probe or automatically using **IPIS**, the position of the datum magnet and the other magnetic rings needs to be verified after the inclinometer casing is installed and grouted in the borehole.

For verifying the position always use Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe. The IPI version probe has a nylon disc of 55 mm diameter for centring the probe inside the inclinometer casing.

Spider magnets used for manual and automatic monitoring are different from each other and must be accordingly ordered.

For verifying the position of the ring magnets outside the access casing, always take the depth reading of each magnet at the beginning of first buzz while lowering the probe into the casing. The buzz will be long and there may be more than one buzz at every location of the magnet.

The datum magnet is installed 50 cm from the bottom of the borewell. The position of the datum magnet can therefore only be taken with the magnetic extensometer probe and not with the **IPIS**.

NOTE: For verifying the position of the ring magnets outside the access casing, always take the depth reading of each magnet at the beginning of first buzz while lowering the probe into the casing. Always use Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe to take the reading. The extensometer is not a part of the supply and has to be ordered separately.

2 MEASUREMENT OF LATERAL MOVEMENT/SETTLEMENT

The first step is to make a near vertical gage well by installing casing in a borehole, embedding in an earth/rock fill or concrete structure during construction or fixing to face of a completed structure.

With suitable measuring system, a set of initial base reading is taken at given depths within the gage well. These readings forms the reference datum. Subsequent reading sets are compared with this reference datum. All subsequent readings are taken over a period of time at identical depths to provide information on rate, magnitude, and direction of lateral deformation and settlement/heave.

Provided that one end of access casing is known to be fixed, it is possible to obtain a complete profile of the gage well by taking a succession of readings. By comparing these profiles, the horizontal and vertical displacement of gage well at different depths over a period of time is determined.

2.1 Inclinometer system for lateral movement measurement

Inclinometer system is used for reliable measurement of lateral movement in applications like:

- Earth movement in landslide zone
- Detecting shear planes in hydraulic structures
- Measuring stability during construction
- Deflection of diaphragm/retaining walls and piles under load

The inclinometer system provides significant quantitative data on magnitude of inclination and its variation with time. It gives information on pattern of deformation and effectiveness of construction control measures. It helps in monitoring behaviour after construction and indicates potentially dangerous conditions that may adversely affect stability of the structure, its foundation and surrounding area. It also provides basic data for design improvement that will promote safer and economical design and construction.

Encardio-rite offer three type of Inclinometer systems for monitoring profile of the gauge well:

- Model EAN-26M digital inclinometer system for taking manual readings.
- Model EAN-52M in-place inclinometer system for online (automatic) readings.
- Model EAN-61M in-place 3D inclinometer system for online (automatic) readings. In addition to lateral movement, this instrument also monitors settlement.

2.1.1 Encardio-rite model EAN-26M digital inclinometer system

The EAN-26M digital inclinometer system is an accurate instrumentation system for taking manual inclinometer readings.

The system comprises of:

- Inclinometer probe
- Interconnecting cable with reel and cable holder
- Smartphone datalogger
- Accessories (to be ordered separately) including dummy probe, calibration check jig, suspension bracket, prism target with adaptor, settlement point, etc.

The inclinometer probe is passed through entire length of gage well, taking readings at fixed pre-determined depths from bottom to top. A dual accelerometer probe senses inclination of casing in two planes at right angles to each other. Voltage output from probe is directly proportional to sine of angle of inclination of long axis of probe from the vertical. A positive output voltage indicates a negative angle of inclination.



Figure 2-1 Digital inclinometer system

A standard commercially available Android OS based mobile phone is used as a hand held datalogger for recording data from gage well at 0.5 m intervals. The Encardio-rite Digital Inclinometer application is loaded on the mobile phone to enable it to configure and collect data from the digital inclinometer system. It utilises the huge computational and image processing power of mobile phone to display the logged borehole data as tables or different types of graphs. It also has a large data storage capacity. This allows the operator to verify the logged data and investigate any anomaly immediately at site.

For details on model EAN-26M digital inclinometer system, please refer to operating manual # WI 6002.103.

2.1.2 Encardio-rite model EAN-52M in-place inclinometer system (IPI) for online monitoring of lateral movement

In-place inclinometer system consists of a string of inclination sensors positioned inside the inclinometer casing to span the movement zone. Each in-place inclination sensor is fitted with a pair of pivoted sprung wheels. The gage length varies from 1 m to 3 m. When ground movement occurs, it displaces the inclinometer access tubing, causing change in the profile of the in-place inclinometer sensors.

The In-place inclinometer system is connected to an automatic SDI-12 interface datalogger for continuous real-time monitoring of the lateral movement. Continuous data logging and real-time monitoring help to provide an early warning in case of an impending danger or failure.

For details on model EAN-52M in-place inclinometer system, please refer to operating manual # WI 6002.113.

2.1.3 Encardio-rite model EAN-61M in-place 3D inclinometer system (IPIS) for online monitoring of lateral movement and settlement

This system is similar to the above, excepting that settlement along with lateral movement can also be monitored online automatically. Special magnetic ring targets are fixed outside the access casing at specified levels. Monitoring settlement along with lateral movement automatically by using inclinometer casing is very cost effective as it can eliminate the use of separate borehole extensometers.

The in-place 3D inclinometer systems (IPIS) consists of an array of integrated tilt (x-y) cum contactless magnetic sensors (z), installed inside the inclinometer access casing for real-time displacement monitoring in critical applications.



Figure 2-2 In-place inclinometer



Figure 2-3 In-place 3D inclinometer system

The sensors measure tilt and settlement in successive segments to accurately monitor a change in the profile (x-y-z) of the inclinometer casing. Each IPIS sensor is fitted with a pivoted sprung wheel which rest inside the grooves of the inclinometer casing. Successive sensors are connected to each other through gage tubes (with adjustable lengths).

When subsurface movement occurs, it displaces the inclinometer casing, causing a change in tilt of the in-place tilt sensors. This results in a change in the output of the sensors, proportional to the tilt i.e. the angle of inclination from vertical. Simultaneously, if any settlement/heave takes place, it is measured by the position change between the contactless magnetic sensors and the magnet rings fixed outside the inclinometer casing. Settlement/heave of all the sensors is thus determined with respect to a reference which can be the top of the borewell or a datum magnet that can be installed at the bottom of the borewell casing.

The daisy chain of sensors are connected to a data acquisition system for real-time monitoring of lateral movement and settlement. For details on model EAN-61MS in-place 3D inclinometer system, please refer to operating manual # WI 6002.128.

2.1.4 Encardio-rite model EDS-91/2.1 Magnetic settlement probe

Another important instrument which is used is the model EDS-91/2.1-IPI version magnetic probe. The magnetic probe has a reed switch encapsulated inside it in silicon rubber for protection against shock, corrosion and ingress of water. It is connected to the signal receiver consisting of a reel with a battery pack, an on-off switch, buzzer, LED by a flat measuring tape.

For more information, please refer to section 1.4.4 and instruction manual # WI 6002.18 for model EDS-91/2.1 magnetic probe.



Figure 2-4 Magnetic settlement probe

3 ACCESS CASING AND FITTINGS

3.1 EAN-AT70 ABS access casing (70 mm)

ABS access casing has longitudinal keyways, specially produced to close tolerances. Wheels of tilt sensing probe can run smoothly inside these keyways. The casing is self aligning ABS tubing, 70 mm o.d., 58 mm i.d., 3 m in length.

Two kinds of couplings are available to rapidly join access casing. Fixed couplings are normal and telescopic couplings are available in case substantial settlement is expected to take place. The design of the couplings ensures that correct alignment of keyways is maintained throughout the depth of gage well.

Key features

- High precision internal grooves
- Self-aligning, leak-proof couplings
- ABS material and thick walls make it strong enough for use in any kind of application
- Spiral effect, less than 0.3°/3 m



Figure 3-1 Inclinator ABS casing

3.2 EAN-FC70 ABS fixed coupling (70 mm)

77 mm o.d. ABS fixed coupling, 160 mm long, with four internal keyways at 90° to each other.

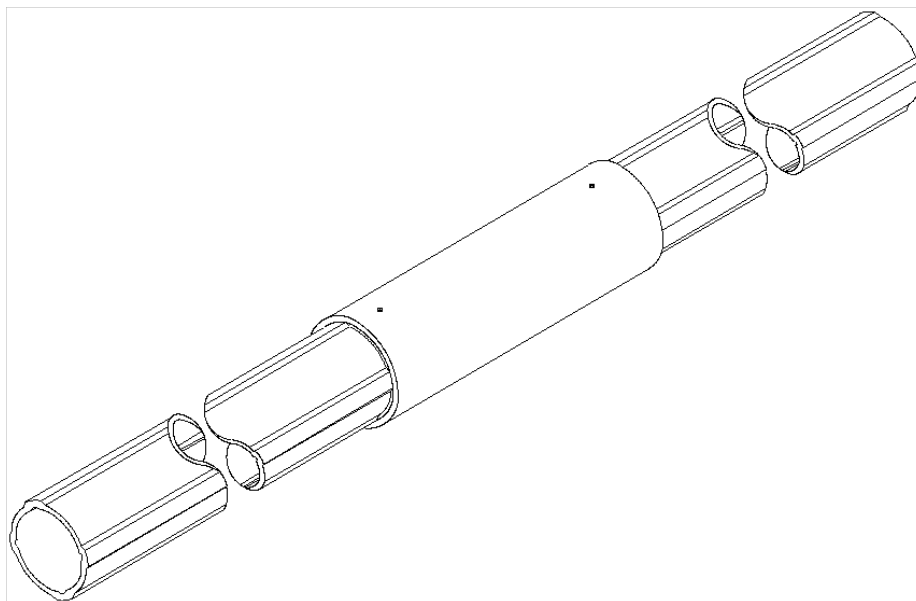


Figure 3-2 ABS casing with fixed coupling

3.3 EAN-TC70 ABS telescopic coupling (70 mm)

77 mm o.d. ABS telescopic coupling, 400 mm long, with four internal keyways at 90° to each other. Displacement 150 mm.

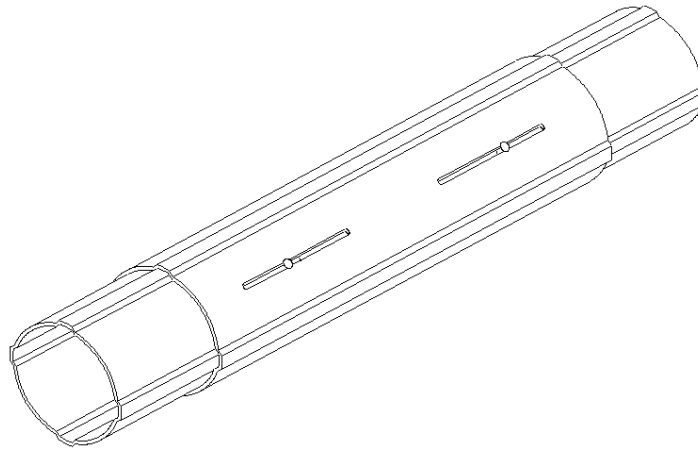


Figure 3-3 ABS casing with telescopic coupling

3.4 Accessories

3.4.1 EAN-EC70 ABS end cap for access casing (70 mm)

ABS cap to fit 70 mm o.d. casing at top or bottom.

3.4.2 EAN-TT70 ABS top cap for access casing (70 mm)

ABS top cap with locking arrangement to fit 70 mm casing at top.

3.4.3 Pop rivets and self-taping screws for ABS casing

Pop rivets packets of 100 numbers for fixed coupling. Self-tapping screws packets of 100 numbers for telescopic coupling.

3.4.4 Pop rivet gun

Hand held manually operated.

3.4.5 Drill machine

Hand operated drill machine with two 3.2 mm diameter drill bits. Optionally a 230 V, 50 Hz operation power drill can also be used.

3.4.6 Mastic tape

50/100 mm wide x 10/5 m long

3.4.7 BOPP tape

50 mm wide x 65 m long BOPP waterproof sealing tape.

3.4.8 EAN-PC Protective cover unit

A lockable protective cover unit made of MS sheet and angle is available with extended Torr steel anchors for grouting at top of hole. The 150 x150 mm protective cover is provided with a hinged cover with lock with an interchangeable key. The cover is painted bright red in colour.

4 MAGNET TARGETS FOR SETTLEMENT MONITORING

Magnets are installed over access tubing for monitoring settlement, where large displacement is expected. Encardio-rite provides a wide variety of magnet assemblies to suit different applications.

4.1 Plate magnets

Model EDS-91/3.1.2 Plate magnet is suitable for installation in embankments/land fills. The 300 mm square magnet assembly with a center hole of 71 mm, easily slides over the access tubing of 70 mm od

4.2 Spider magnets

Spider magnets are used for monitoring settlement in a borehole. The leaves of the spider magnet are made to spring out and grip into the surrounding ground.

Model EDS-91/3.3.2 spider magnet has 6 leaves while model EDS-91/3.4.2 spider magnet has 3 leaves. Both are suitable for 70 mm od access casing. Magnet with 6 leaves are a better choice as it holds the ground firmly.

Model EAN-61MS/8 magnet ring with 6 leaves are specially designed for model EPS-61MS 3D IPIS system for automatic monitoring of lateral movement with settlement/heave i.e. displacements in X-Y-Z directions.



Figure 4-1 Different type of magnets for access casing (70 mm od)

4.3 Datum ring magnets

For taking manual readings with model EDS-91/2.1 Magnetic settlement probe, model EDS-91/3.2.2 Datum ring magnet with 71 mm id is fixed permanently near the bottom of 70 mm od access tubing for datum (fixed reading). In an embankment fill the datum magnet is fixed on a 30 cm square plate. For use in a borehole, it is tightened with screws on the inclinometer casing.

In case of **IPIS**, the construction of the datum magnet and the spider magnets is quite different from those used for manual monitoring. The magnets used for manual settlement monitoring cannot be used for this purpose and have to be ordered separately.

5 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

It should be ensured that following tools and accessories required for proper installation of the inclinometer PVC casing:

- 1 Dummy probe – Encardio-rite model EAN-26DP
- 2 Digital Inclinometer probe – Encardio-rite model EAN-26M
- 3 Prism target and mounting accessories
- 4 Settlement monitoring pin
- 5 Magnetic probe with cable reel assembly – Encardio-rite model EDS-91/2.1-IPI version in case settlement is to be monitored
- 6 Tool box
- 7 50 mm wide water proof sealing tape
- 8 Spanner 16/18
- 9 Screw driver 100 mm
- 10 Voltage tester
- 11 Pliers 150 mm
- 12 Flat file 150 mm
- 13 Hand saw with three 30 cm blades
- 14 Drill with a 3.15 mm spare drill bit
- 15 Safety line or tension cable in case hole is very deep
- 16 Clean water supply to clean casing
- 17 Casing collar protection if required
- 18 Grout tube - requisite length
- 19 Acetone
- 20 Aluminium pop rivets - four per joint plus some extra
- 21 Pop rivet gun
- 22 Casing clamps - 2 sets
- 23 Plumb bob with 5 m chord
- 24 Casing cap with guy ropes (for embankment installations)
- 25 Casing 'U' clamps and grout bolts (For installation on concrete structures)
- 26 Pull cord (if spider magnets are to be installed)

6 PRE-ASSEMBLY OF CASING

6.1 Casing storage

- Do not apply too much load or force on casing.
- Store all items in a proper place in a ventilated building under shade of a roof
- Do not warp or bend during storage.
- Avoid direct sunlight on plastic casing and accessories as it can cause deformation of casing.

6.2 General instructions

Following general instructions for installing ABS casing are typical practices in the field and may require modification to suit specific conditions and applications at site.

Inspect casing to ensure that damage in transit or storage has not occurred. See that ends and interior of casing are clean.

Store casing horizontally, fully supported and away from sunlight. This will prevent it from getting damaged or distorted. Number each length and assemble numerically to avoid errors and confirm correct depth.

CAUTION: Do not apply too much axial load on casing as it may damage casing by cracking. Also do not drop casing.

Casing may be installed in a borehole, embedded in an earth/rock fill or concrete structure during construction or fixed to vertical face of a completed structure. Installation on completed structure is not being described in this manual, as it is easy with help of casing clamps that may be separately procured.

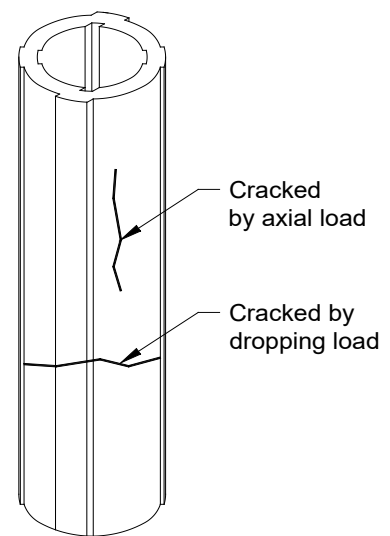


Figure 6-1 Checking of casing

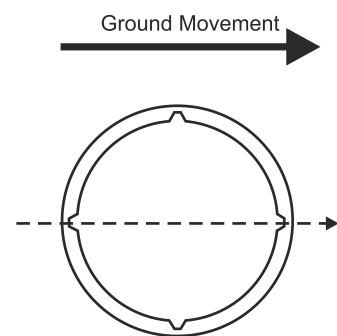
6.3 Alignment of casing

Maintain one pair of casing grooves perpendicular to direction in which lateral movement is to be measured. If no such direction is known, maintain one set of grooves parallel to N-S direction.

6.4 Preparation of casing before installation

NOTE: Pre-assembly and storage of inclinometer casings should be done in shade as prolonged exposure to direct sun light might distort the tubes.

- Clean inside of bottom cap and outside of lower end of a casing with moist cloth (use isopropyl alcohol if greasy).
- Push bottom end cap over casing. Fix it to casing with four pop rivets using 3.2 mm diameter drill bit. Riveting should be done at diametrically opposite points 90° apart.
- Seal joint between bottom cap and casing with mastic waterproof tape. One round of this tape with 10 mm overlap is sufficient. Press tape firmly after applying, to remove any air pocket.
- Additionally wrap three to four rounds of BOPP tape with a little force over mastic tape for extra protection (refer to figure 6-2). Proper sealing is necessary to prevent intrusion of backfill materials inside casing.



6.4.1 Fixed coupling

- a. Attach a fixed coupling each to one end of all other casings to be installed. Clean mating surfaces with moist cloth (use isopropyl alcohol if greasy).
- b. Push 160 mm long fixed coupling over end of casing up to maximum allowable depth of around 80 mm. Drill holes with 3.2 mm bit and pop rivet coupling to casing at four places (position for two pop rivet holes are marked on coupling; other two holes should be symmetrically drilled).
- c. Seal joint between fixed coupling and casing with mastic waterproof tape and BOPP tape as described above in § 6.4 (c) and 6.4 (d).

6.4.2 Telescopic coupling

Telescopic couplings are mostly installed in embankments where settlement takes place during construction. They are sometimes installed in boreholes also where large settlement or heave may take place. Telescopic coupling has two sets of diametrically opposite longitudinal grooves which facilitate a total movement up to 150 mm (refer to figures 6-4 and 6-5). Coupling is secured to adjacent casings with a set of four screws and nylon washers.



Figure 6-2 Preparation of casing

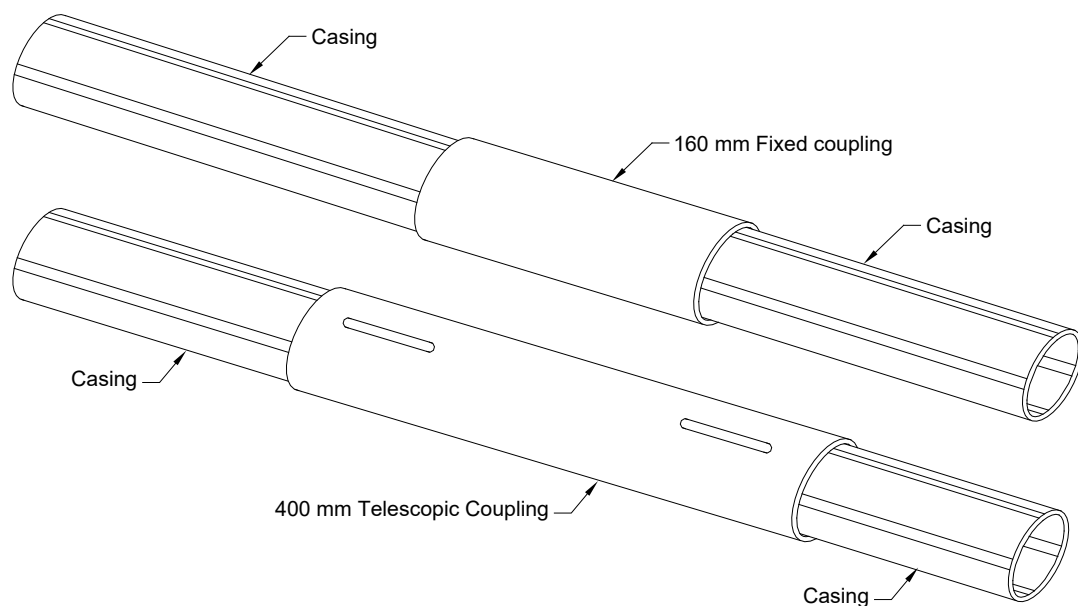


Figure 6-3 Fixed & telescopic couplings

- a. Attach a telescopic coupling each to one end of all other casings to be installed excepting the one with the bottom cap. Clean mating surfaces with moist cloth (use isopropyl alcohol if greasy).
- b. For applications in which only settlement takes place push 400 mm long telescopic coupling over end of casing up to maximum allowable depth of around 195 mm. Drill two holes with 2.5 mm bit at end of slot of coupling as shown in figures 6-4. Fix coupling to casing with self-tapping screws and washers at position A. (Position B is location where the other casing will be drilled during installation at site).
- c. Pull casing out so that screw comes to position C as shown in figure 6-6. Tighten screws. Do not over tighten. When the other casing is finally assembled at site, a space of 150 mm will be left between the casing ends to take care of settlement.
- d. In case settlement/ heave are both possible at location where casing is to be installed, adjust position of screws in groove for an appropriate length of travel as shown in figure 6-6. If such a casing is required to be lowered from top into a borehole, aluminium pop rivets may have to be used to keep coupling in position (refer to figure 6-6). Seal joint between telescopic coupling and casing with mastic waterproof tape and BOPP tape as described in § 6.4 (c) and 6.4 (d).
- e. The casing assemblies are now ready for installation. Carefully transport them to site when required.

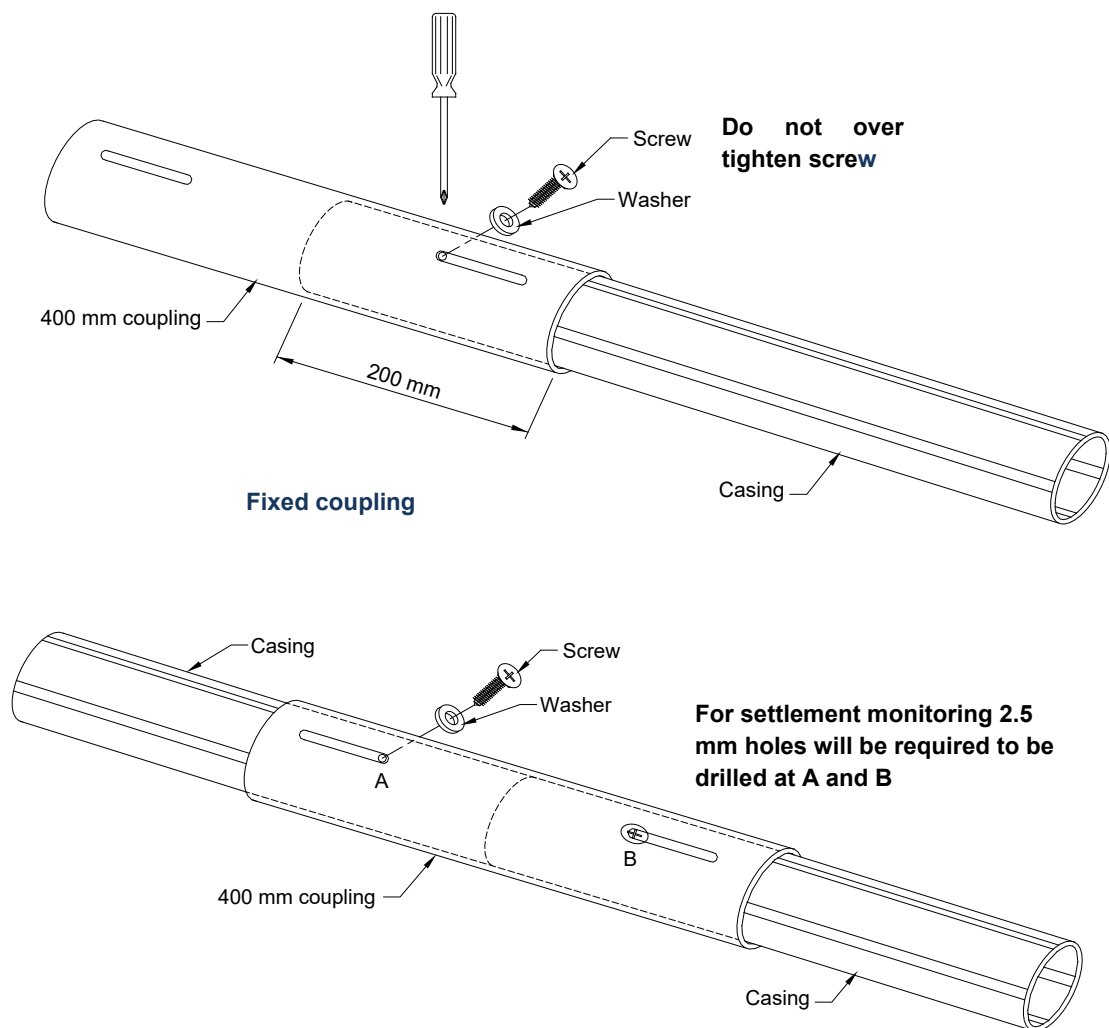
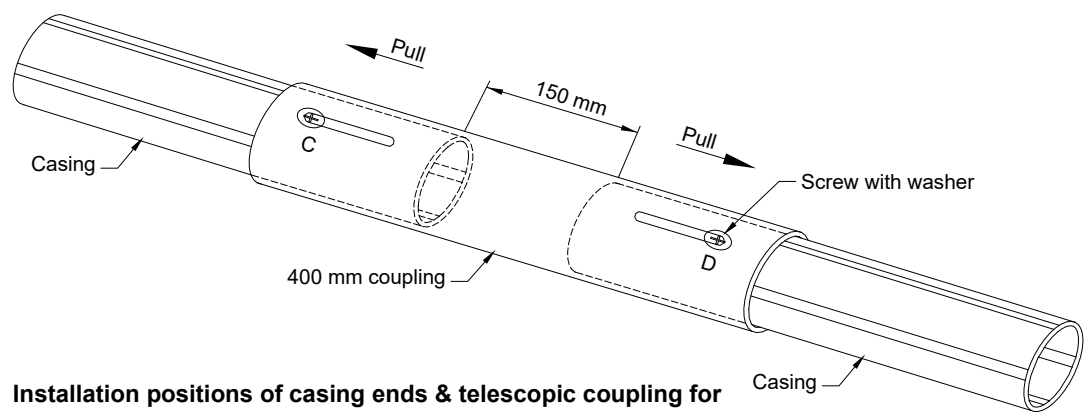
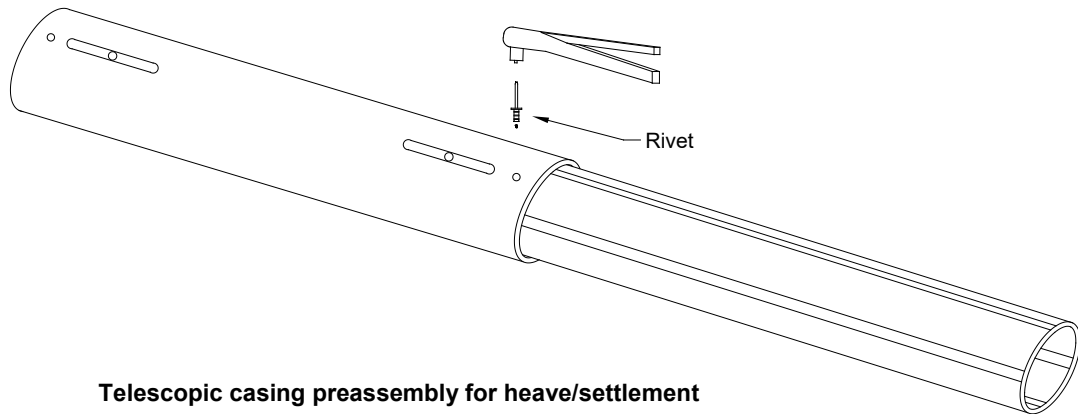


Figure 6-4 Fixed and telescopic coupling



Installation positions of casing ends & telescopic coupling for settlement monitoring



Telescopic casing preassembly for heave/settlement applications

Figure 6-5 Fixing telescopic coupling for heave/settlement monitoring

7 INSTALLATION IN BOREHOLE

7.1 Borehole drilling

- a. Drill 125 mm diameter hole as vertical as possible around 0.5 m more than planned depth of inclinometer casing. The drill hole diameter should facilitate grouting around outside of casing. A mobile rotary drilling rig using rotary wash boring technique may be used to perform the drilling. Wash borehole clean and verify that it is not blocked anywhere upto bottom. To prevent sidewalls of borehole from collapsing, casing along with bentonite slurry may be used.

NOTE: If necessary, use suitable steel casing to prevent sidewalls of borehole from collapsing. In such a case, steel casing will have to be gradually withdrawn as grout is pumped into borehole.

NOTE: In case spider magnets are used around casing for settlement monitoring, drill hole diameter should preferably be 150 mm.

7.2 Installation of inclinometer casing in borehole

- a. Lower casing with bottom cap into borehole gripping it with safety clamp secured around 500 mm from top.

NOTE: Ensure the grooving alignment as mentioned above.

- b. Take a casing pre-assembled with fixed coupling. Secure a safety clamp around 500 mm from its top end and mate coupling end with casing already lowered. Pop-rivet fixed coupling to casing at four places.
- c. Seal joint with mastic waterproof tape and BOPP tape, as described in § 6.4 (c & d).
- d. Remove safety clamp from first casing and lower jointed casings into guide pipe/borehole.
- e. To counteract buoyancy, if required fill casing with clean water to lower it into guide pipe/borehole.
- f. Repeat above procedure for all casings to be installed in borehole.

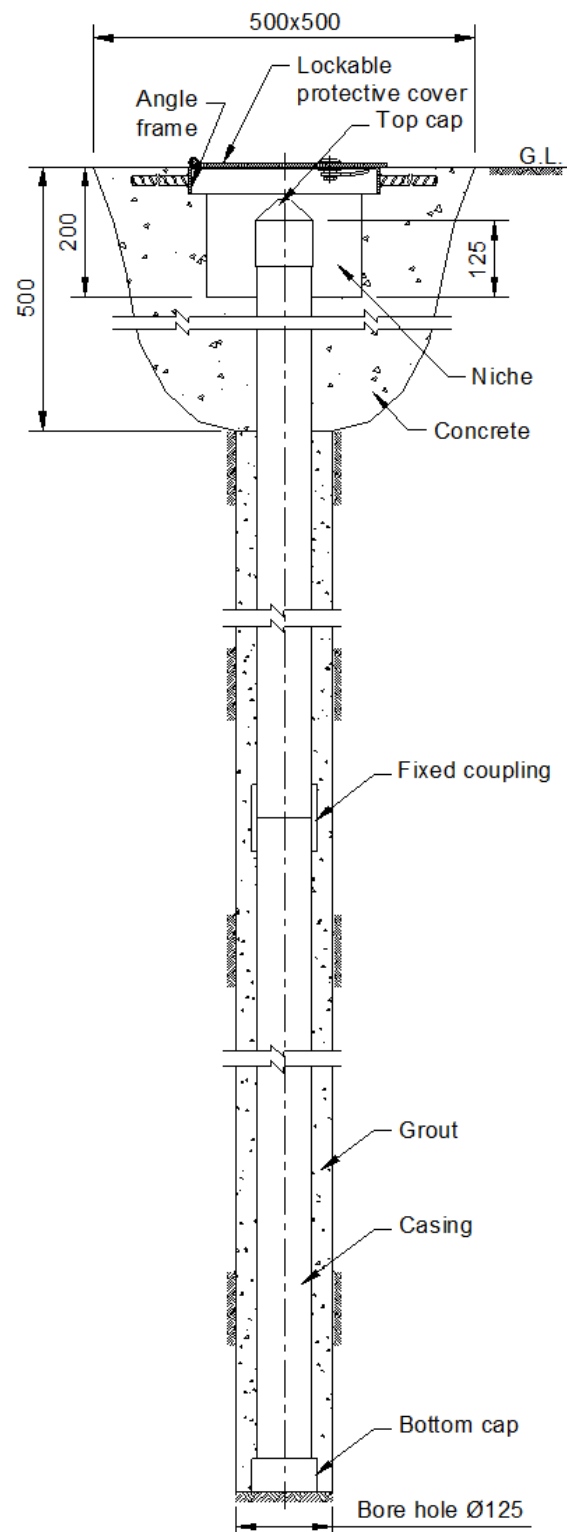


Figure 7-1 Checking of casing

NOTE: Overcoming buoyancy while lowering of casing: Casing will be buoyant if borehole is water or mud filled and must be filled with water to install it in borehole.

CAUTION: Do not accidentally drop casing into borehole. During insertion of casing sections, clamps should be used at top of hole to prevent lower casing sections from falling to bottom of hole. For very deep installations, a tension cable may be attached to bottom of casing to relieve tension on upper casing couplings. During process of lowering, casing grooves should be kept aligned to final configuration desired so that later turning of casing is minimized.

CAUTION: When casing reaches correct depth; check proper installation with dummy probe. If probe will not pass or jumps track, pull casing out and rectify problem.

7.3 Grouting in borehole

- Grout casings as directed by project authorities. Ideally, grout should be mixed to match strength and deformation characteristics of material around borehole. In practice, main consideration is to use a grout that allows casing to move with surrounding material. For information, grout mixes used by some authorities are as follows:

Hard and medium soils

Cement	50 kg
Bentonite	15 kg
Water	125 litres

28-day compressive strength was about 350 kPa.

Soft soil

Cement	50 kg
Bentonite	20 kg
Water	325 litres

28-day compressive strength was about 30 kPa.



Figure 7-2 Casing installation

NOTE: Please verify above values yourself in actual conditions before use. Encardio-rite takes no responsibility for correctness of above information at your site as the compressive strength values are dependent upon geology of site and environmental conditions.

- b. For mixing grout use a grout mixer or circulation method (figure 7-3), in case a mixer is not available. In the **circulation method**, a rig pump or a trash pump coupled to a gasoline engine is used for mixing the grout components i.e. water, cement and bentonite. Subsequently, the same pump can be used for pumping the grout to the bottom of the borehole. It is to be noted that pressure grouting is not required as the grout flows down under gravity.
- c. Add cement to water first and mix/circulate. Add bentonite in small quantities slowly during the mixing/circulation process such that lumps of bentonite are not formed. Adjust amount of bentonite to produce a grout within consistency of heavy cream. If grout is too thin, the solids and water will separate. If the grout is too thick, it will be difficult to pump.
- d. Pull out and dismantle grout pipes one by one as the hole is being filled with grout.

NOTE: Use a mixer, a grout pump, a pipe or hose for delivering grout. Do not mix grout by hand. Also do not use a water pump to place grout, since pumping grout would damage it.

Properly mixed grout should be free of lumps. It has to be thin enough to pump but thick enough to set in a reasonable length of time. If mixture is too watery, it will shrink excessively, leaving upper portion of the borehole un-grouted. Avoid use of admixtures and grouts that cure at high temperature since these may damage the casing.

The use of hydrated lime rather than cement is sometimes recommended to provide for a more responsive, somewhat weaker backfill.

For plastic casing, heat of hydration of grout or excess grout pressure can deform the plastic. This problem can be eliminated by maintaining casing full of water until grout has set or by grouting hole in stages.

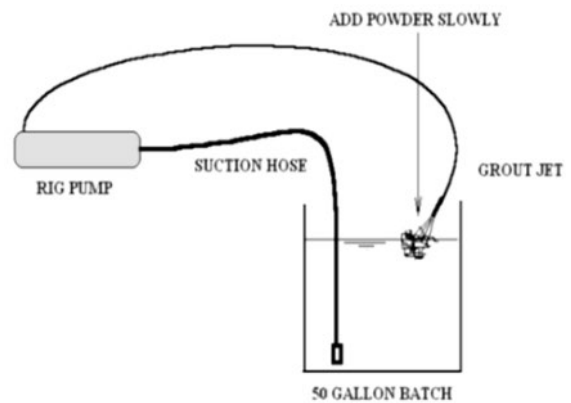


Figure 7-3 Circulation method of pumping grout

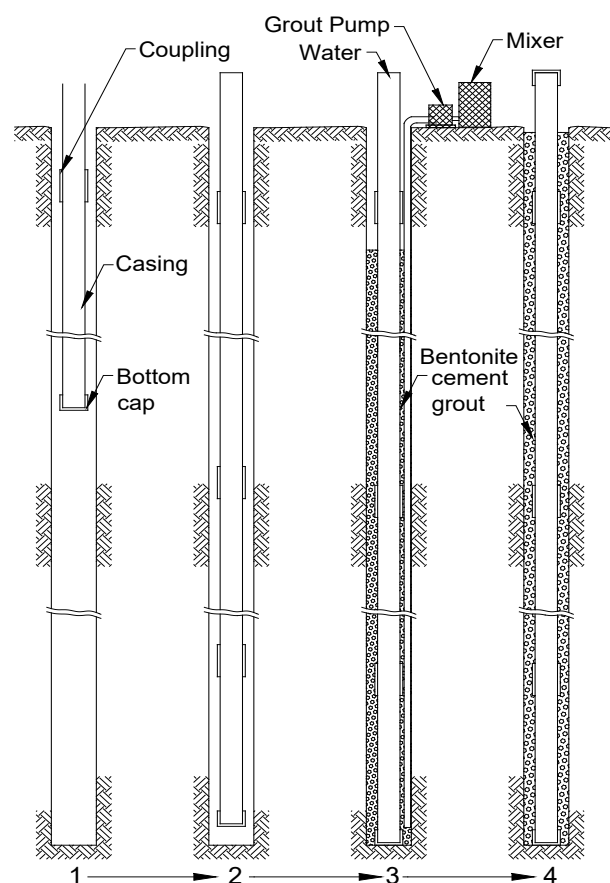


Figure 7-4 Grouting by tremie method

CAUTION: Experience shows that sand or pea gravel should not be used as backfill material unless it is absolutely necessary. These backfill tend to mask movement, not allowing a rigid shear plane to reach the casing.

- e. For grouting the inclinometer casing in the borehole use of **tremie method** is recommended (figure 7-4). Lower 20 mm nominal diameter rigid PVC pipe lengths jointed using threaded sockets to around 0.5 m above the bottom of the borehole.



Figure 7-5 Grout overflowing (instead of water) denotes grouting is complete

NOTE: Pre-grouting is sometimes done in case of a shallow borehole. It is also useful when there is not enough space for the grout pipe in the annulus between the casing and the borehole wall.

- f. Flush inside of casing with clean water after grouting to prevent any leaked in grout from sticking to inside of casing and impairing movement of probe.

7.4 Stage grouting in deep borehole

Boreholes deeper than 30 m require special care while grouting to prevent the grout pressure from collapsing the casing.

Also, when grout, which has a density of 1280 kg per cubic meter, is pumped into borehole, water-filled casing becomes buoyant because grout is denser than water.

To counter this buoyancy/collapsing of casing, following methods can be used (depending on depth of borehole and site requirements):

7.4.1 Option 1: Fixing casing bottom by grout

A two stage grouting process can be carried out, where the first pipe extends to the bottom of the borehole and the next pipe extends to bottom of the next stage.

In the first stage, bottom 10~15 m (20~25 m for very deep borehole) can be grouted and left for sufficient time (at least 12 hr) to set. For this, the volume of grout needs to be calculated (grouting depth for stage 1 + around 30% extra). Once grout is set, it will hold the bottom and overcome the buoyancy due to the grout which is denser than water. Rest of the hole can be grouted using tremie method.

NOTE: Each grout pipe needs to be labelled or color coded properly to avoid accidentally pumping grout or water down the wrong pipe.

During stage grouting, provisions need to be made to overcome the uplift force due to the first stage grouting. For this, a clamp can be installed at the topmost casing of the installation and tied to a firm object. Or suitable down force can be applied using steel pipe or weight as mentioned below.

7.4.2 Option 2: Using steel pipe inside casing

A down force can be applied at bottom of casing by lowering a steel pipe of suitable weight and length (calculated depending on depth and dia of borehole) to bottom of casing. This needs to be done until grout is set. It must be ensured that the bottom cap is securely fixed.

7.4.3 Option 3: Using weights at bottom

A non-retrievable weight can be suspended from the bottom casing before lowering it in borehole. This method is however cannot be used in very deep boreholes.

7.4.4 Option 4: Using special anchor at bottom

A suitable anchor (spider type or hydraulically actuated anchor) can be attached to the bottom most casing to hold the complete casing length in place.

NOTE: Do not park a drill rig over the casing or apply any other top-down method of counteracting buoyancy. Putting weight at the top of the installed tubes to overcome the upward force due to buoyancy is not recommended, as it tends to distort the casing.

7.5 Top cover

- a. Fix protective cover in concrete platform on top of borehole. Protective covers feature a universal key and dust protection for lock (always put back dust protection after locking to avoid lock jamming). Typical dimensions for concrete platform are given in figure 7-1. These may vary depending on local site conditions.

Top of upper most casing should be kept below final ground level and protected by top cap and lockable manhole cover. Cut top of pipe suitably by a hacksaw. Use flat file to make pipe end smooth.



Figure 7-6 Protection for inclinometer

7.6 After installation check

- a. Check installed access tubing by dummy probe (EAN-26/2.2) for smooth movement up to bottom of borehole.

NOTE: Top of uppermost casing should be 125 mm above base of niche as shown in figure 7-1. The niche is around 200 mm deep. This is necessary for fixing pipe extension jig over casing for taking readings.

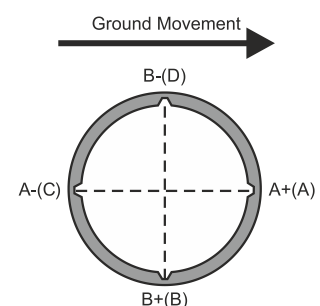
- b. When not taking readings, gage well should be protected by top cap and manhole cover should be kept locked.
- c. Mark tag no. of the installation with paint on inner side of hinged cover.

NOTE: Plying of heavy machinery such as cranes, loaded trucks etc. near protective cover should not be allowed and if required proper fencing with warning flags should be provided. In case it is not possible to avoid movement of heavy machinery over protective cover, specially procure heavy duty covers from factory and embed in a heavy concrete platform.

NOTE: If telescopic coupling is used, settlement sections must be inserted appropriately extended or collapsed. Grease telescopic joint and use mastic and BOPP tape to keep telescopic section at required opening and also to prevent intrusion of grout or backfill materials inside casing.

7.7 Marking of grooves (sign convention)

Mark casing grooves as 'A+', 'B+', 'A-' and 'B-' with permanent ink marker pen. If uppermost probe wheel is pointed in direction of major principle plane of movement, casing groove pointing in this direction is marked as 'A+'. Looking down the well, directions 'B+', 'A-' and 'B-' are clockwise from 'A+'.



7.8 Fixing magnets

Where settlement reading is also required with lateral movement, datum and leaf spring (spider) magnets are mounted on the inclinometer casing. Different type of magnet assemblies available are described in section 5.

1. Before lowering the bottom most casing, fix the datum magnet assembly (refer to figure 7-7) firmly to the access tubing with the screws provided, 0.5 m above the bottom cap.

NOTE: Since in most cases the bottom of inclinometer access tubing is located in solid ground (fixed), the datum magnet becomes a benchmark. This tubing will be used as bottom most tubing. All the other magnet assembly readings are referred to this datum magnet to get their respective absolute settlement relative to the benchmark.

Datum and spider ring magnets are different for manual and automatic monitoring and should be ordered separately according to requirement

2. Before lowering the second casing, position the spider magnet on casing at the desired location. Fix it with waterproof sealing tape (refer to figure 7-8) on the access casing. For example, in case the desired interval between the magnets is 3 m, the spring magnet will be fixed on the access casing, which comes in 3 m length, 0.5 m above the bottom of casing (to maintain 3 m interval from datum magnet).
3. Close the leaf spring legs of the magnet with release wire link and release pin provided with supply. Lock the release wire link with release pin, holding the leaves tightly to compress them. This will allow easy lowering of the casing into borewell.

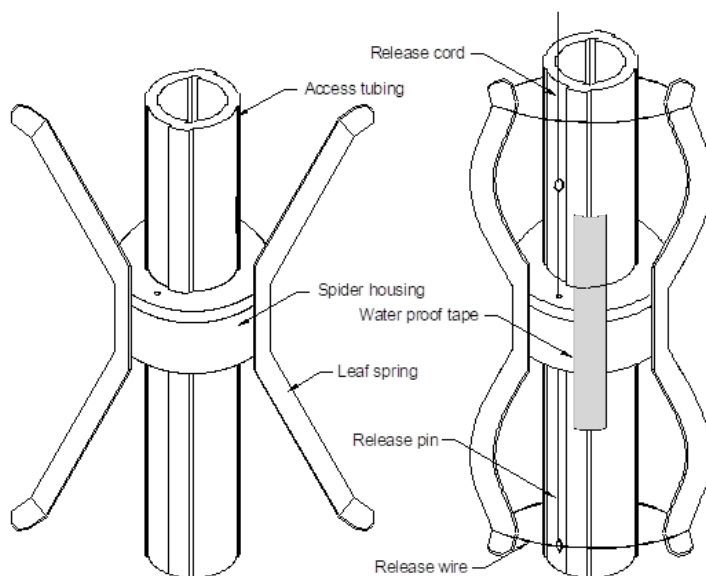


Figure 7-7 Datum magnet fixed on bottom most casing



Six leg spider magnet placed over access casing



Magnet fixed with sealing tape; leaves compressed with release wire link and pulling cord

Figure 7-8 Spider magnet installation on access casing

4. Tie the pulling cord (fishing cord) to the head of release pin so that it may be pulled from the top to release the spider arms.

CAUTION: The spider magnets are provided with two holes on the magnet housing (refer to figure 7-9). Ensure that at least one of the holes of the magnet housing is aligned with the hole of other magnets fixed on different casings. This will ensure that all release pin are aligned with each other and can be pulled out from the release wire link easily.

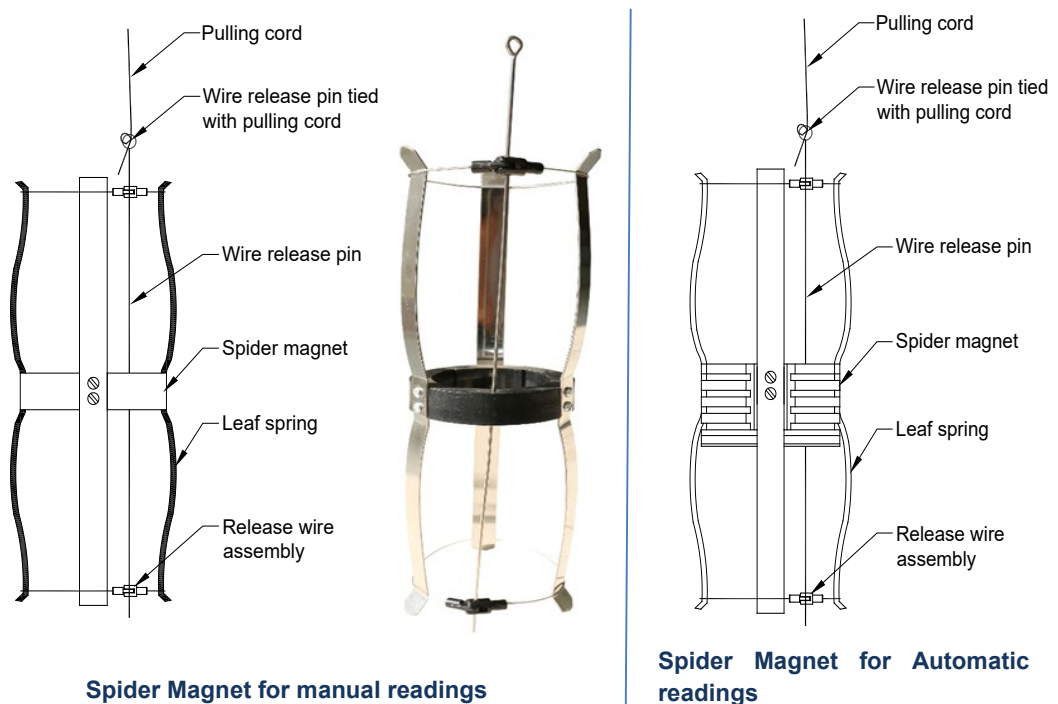


Figure 7-9 Magnet leaves compressed with release wire link and pulling cord

NOTE: Ensure that at least one leaf (of magnet) is aligned with the groove of the access casing. This will make releasing the spider leaf easier and also in pushing the grout pipe safely.

5. Install the remaining spider magnets at desired locations in a similar way before lowering other casings.

CAUTION: Each spider magnet will have a different pulling cord to lock its release wire link. Mark each cord precisely, taking the bottom most magnet (magnet which is just above the datum magnet) as # 1.

Ensure that release cord (fish cord) does not get entangled while lowering of casings.

6. Once all the casing are lowered with spider magnets i.e. on reaching the top of the installation, release spider magnet leaf springs by puling the pulling cord one by one, starting from bottom most magnet.

NOTE: For automatic settlement readings, special ring spider magnets are used, as explained in section 2.1.3 and 4.2. Please refer to manual # WI 6002.128 on EAN-61MS in-place 3D inclinometer system, for detail installation of the same.

8 INSTALLATION IN DIAPHRAGM WALL OR PILE

8.1 Preparation for installation in D-wall – MS casing

Direct installation of inclinometer casing in diaphragm wall or a pile is problematic. It should be avoided. Inclinometer casing will get distorted and stressed when firmly tied to steel structure from bottom to top.

It is also not good to directly expose the casing to heat of hydration and stresses generated during the concreting process. Casing may distort and even get cracked.

- a. Fix a 150 mm nominal bore diameter steel guide pipe vertically within reinforced bar cage as shown in figure 8-1. The pipe length to be installed should be worked out in such a way that its top remains around 0.5 m above the existing ground level after cage is fully lowered to bottom of the slurry trench. Bottom of guide pipe should be around 0.5 m above bottom level of cage. It should be sealed at bottom with a concrete plug/plastic cap.

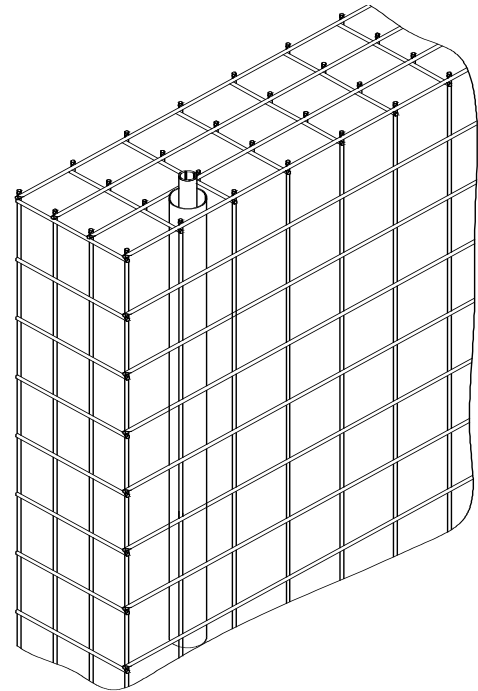


Figure 8-1 Inclinometer casing in D-wall

Make sure that jointing of tube lengths is water proof to prevent any grout/concrete from entering pipe, while cage is being concreted. Use of dented or distorted pipes shall not be done as this will make installation of inclinometer access tube difficult or even impossible.

NOTE: It is recommended that an auxiliary guide pipe be installed adjacent to the main guide pipe at 1.25 m approx. centre to centre distance at critical monitoring locations. This auxiliary pipe can be used in case main pipe gets choked and becomes useless due to any reason.

- b. Weld or fasten guide pipe securely to cage. Ensure that it remains vertical and is least distorted during lowering of cage.
- c. Concrete cage after covering mouth of guide pipe.
- d. Flush guide pipe clean with water and verify depth with help of a suitable depth measuring device (e.g. a sounding chain) that it is fully open up to the bottom.

NOTE: Ensure that heat of hydration of mass concrete has dissipated before installing access casing in guide pipe. Use a temperature probe for this purpose. Temperature should not exceed 40°C. The heat of hydration, if present may warp access casing and render installation useless.

8.2 Installation of inclinometer casing in MS casing (D-wall)

- a. Lower casing with bottom cap into guide pipe gripping it with the safety clamp secured around 500 mm from top.

NOTE: Maintain one pair of casing grooves parallel to the direction in which lateral movement is to be measured i.e. perpendicular to the diaphragm wall.

- b. Take a casing pre-assembled with a fixed coupling, having a safety clamp secured around 500 mm from its top end and mate it with the pipe already lowered through the coupling end. Pop-rivet the fixed coupling to lowered casing at four places.

- c. Seal joint with mastic waterproof tape and BOPP tape, as described in § 6.4.
- d. Remove safety clamp from first casing and lower jointed casings into guide pipe.

NOTE: Always use safety clamp such that casing does not accidentally fall into guide pipe while installing.

- e. To counteract buoyancy, if required fill casing with clean water to lower it into the guide pipe.
- f. Repeat above procedure for all the casings to be installed in the guide pipe.

NOTE: It is preferable to use 20 mm nominal diameter rigid PVC pipe lengths jointed using threaded sockets for grouting. Lower above tubes say up to 0.5 m above bottom of guide pipe.



Figure 8-2 Installation of MS casing in diaphragm wall cage

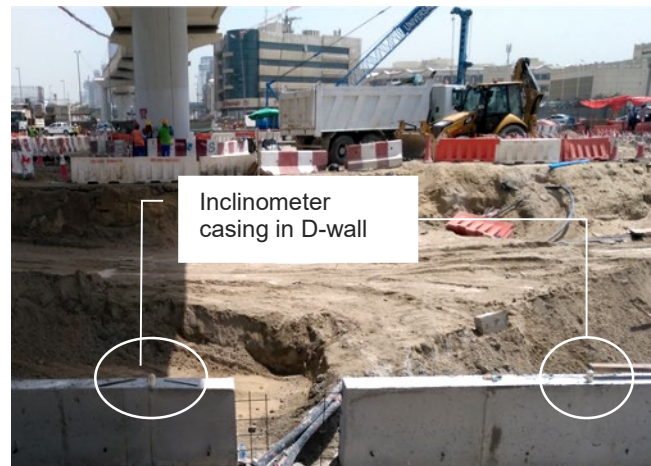


Figure 8-3 Inclinometer casing installed in diaphragm wall

8.3 Grouting in MS casing (D-wall)

- a. Prepare a grout mix to be filled in the annular space between the guide pipe and casings as directed by project authorities. If no instructions are available, suggested grout mix is as follows:

Cement	50 kg
Bentonite	10 kg
Water	75 litres

- b. It is recommended to flush inside of casing with water after grouting. This is to prevent any leaked in grout from sticking in the casing and impairing the movement of the probe.

8.4 Top cover

- a. Top of uppermost casing should be 25 mm above top of steel pipe. Cut top of pipe suitably by a hacksaw. Use flat file to make the pipe end smooth.

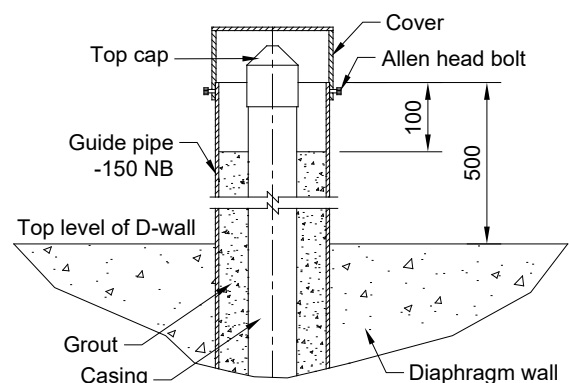


Figure 8-4 Protection of casing in diaphragm wall

NOTE: Depth of top of grout face from top of steel casing should be at least 100 mm (125 mm from ABS casing top) as shown in figure 8-4. This is necessary for fixing pipe extension jig over casing for taking readings.

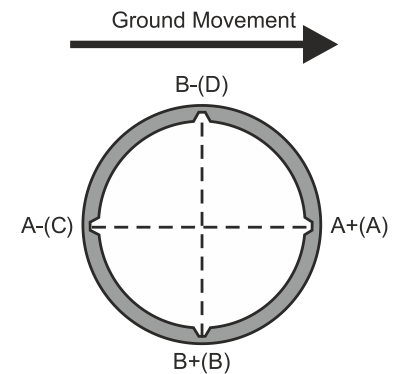
- b. Clean exposed portion of casing top and fix top cap.
- c. When not taking readings, the gage well should be protected with cover fixed to top of steel casing by four M6 Allen head bolts (figure 8-4).

8.5 After installation checks

- a. Check installed guide pipe for proper installation before installation of access tubing. Ensure that it is sufficiently vertical and is least distorted.
- b. Check installed access tubing by dummy probe (EAN-26/2.2) before lowering inclinometer probe.
- c. Ensure fixing protection cover and placing top cap after installation of inclinometer casing.

8.6 Marking of grooves (sign convention)

- a. Mark tag no. of installation in paint on inner side of steel guide pipe. Also mark casing grooves as 'A+', 'A-', 'B+' and 'B-' with permanent ink marker pen. If uppermost probe wheel is pointed in direction of the major principle plane of movement, the casing groove pointing in this direction is marked as 'A+'. Looking down the well, directions 'B+', 'A-' and 'B-' are clockwise from 'A'.



NOTE: Plying of heavy machinery such as cranes, loaded trucks etc. over the installation should not be allowed and if required proper fencing with warning flags should be provided. If necessary, the guide pipe with inclinometer casing be cut short to just above the diaphragm wall top level and a lockable hinged cover be provided. Readings can be taken using an extension jig.

9 INSTALLATION IN DAM EMBANKMENT (FILL) – CORE SECTION

9.1 Precaution for installation in embankment fill (core)

- a. In an embankment installation like in a dam, settlement will take place and coupling selected should be long enough to provide for anticipated settlement. Encardio-rite ABS telescopic coupling provides for a displacement of 150 mm.
- b. Telescopic type slip joints are usually used only in embankment, but if settlement is anticipated below a dam, they may be used in foundation also.
- c. While installation, maintain one groove of inclinometer casing orientated in the direction in which maximum deflection is expected. If the deflection direction cannot be determined, orient north/south.
- d. Alignment of grooves (of casing) must be maintained throughout the installation process, to avoid inducing torsion to the casing thereby causing spiral of the grooves.

9.2 Protection of installation in embankment fill (core)

- a. As the installation progresses in stages over a few months, it is essential that the inclinometer casings be properly protected against damage. The followings precautionary steps are recommended.
 - The contractor has to fabricate a circular fencing of G.I. wire with top & bottom end open (2 m dia.) duly flagged, for protection of plastic casing from accidental damage due to nearby construction work. This fencing can be manually raised, as and when the embankment height is raised.
 - The exposed top end of the inclinometer casing shall always be kept covered with the help of top cap to prevent any loose soil or rock debris from entering the inclinometer casing.
- b. Inclinometer casing in embankment installation can warp from extended exposure to hot sunlight. The exposed part of the inclinometer casing should therefore be properly shielded from sunlight. Suitably cover exposed part of inclinometer casing with tarpaulin or thick black plastic sheet to protect plastic casings from unnecessary exposure to strong sunlight. Ultra violet radiation in sun rays cause faster weathering of the plastic material. Once casings are fully embedded in soil they are safe.
- c. A settlement marker should be provided adjacent to top of inclinometer casing that will serve as survey reference point. This will allow inclinometer as well as settlement profile to be referenced to an absolute reference (elevation above sea level) should bottom reference be lost due to any reason.

9.3 Installation of casing in embankment fill (core)

- a. The first casing to be installed is the one with the bottom cap. Orient casing vertically with help of casing top cap and guy ropes. Use plumb bob for this purpose. Ensure that one groove is oriented in direction of maximum deflection.
- b. It is good practice to grout fix lower end of casing. Effort should be made to install casing plumb within 1° from vertical.
- c. Remove casing cap and guy ropes as soon as possible because these will have to be re-used as installation continues.
- d. Compact soil carefully around casing and let level rise to around 20 cm below top of casing.

NOTE: An inclinometer installation in embankment requires no special backfill. The soil used for embankment is compacted carefully around the casing.

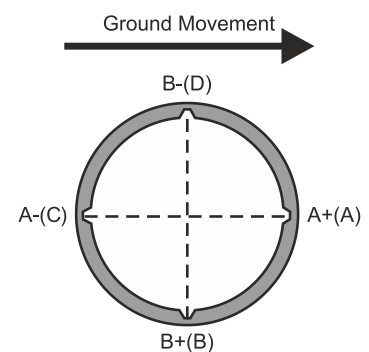
- e. Assemble telescopic coupling using acetone for cleaning and pop rivets, mastic & BOPP tape for jointing suitably extending telescopic coupling to accommodate the expected settlement/rebound as described in § 6. Grease telescopic joint as a bond breaker for the back fill. Properly seal by mastic and BOPP tape to prevent intrusion of backfill materials inside casing.
- f. Assemble next casing to telescopic coupling using procedure described above.
- g. Repeat procedure till all casings and telescopic couplings are assembled. This of course will have to go along with the filling of the embankment.

NOTE: In case settlement has also to be monitored, install plate magnets as the required level is reached.

- h. Flush inside of casing with water during assembly and after it is fully assembled. This is to prevent any back fill or dirt from sticking on to grooves in casing and impairing movement of probe. Always keep top of casing well plugged with top plug.

9.4 Marking of grooves (sign convention)

Mark the casing grooves as 'A', 'B', 'C' and 'D' with a permanent ink marker pen. If the uppermost torpedo wheel is pointed in the direction of the principal plane of movement, the casing groove pointing in this direction is marked as 'A'. Looking down the well, directions 'C', 'B' and 'D' are clockwise from 'A'.



9.5 Top protection

The top of the upper most casing should project around 150 mm above the ground level. Fix the protective top cap and lock it. When not taking readings, the gage well should be protected with the top cap and locked.

10 INSTALLATION IN DAM EMBANKMENT (FILL) – CREST

10.1 Precaution for installation in crest/rockfill section

- Procedure for installation of casing in core and crest is different as crest area principally consists of rock aggregates varying in size. This type of rock fill may show considerable lateral shift with large localized variation along the depth. Localized lateral movement in rock fill is often beyond allowed deformation limits of standard inclinometer casings causing casings to either shear off or crush.
- Surrounding inclinometer casings with graded fine sand or clay up to some distance may not help as it has been observed that due to piping effect, fine fill material can easily drain off through voids in surrounding large rock aggregate fill matrix. Loss of fill material around inclinometer casings may give rise to cavities that cause rock pieces from surrounding rock fill matrix to come loose and strike inclinometer casing causing catastrophic damage to the casings.

10.2 Protection of installation in crest/rockfill section

Same as mentioned in section 8 above (protection of installation in embankment fill-core).

10.3 Installation of casing in crest/rockfill section

- Before installation the location of the inclinometer casing (northing & easting) should be properly marked by surveying.
- Generally following installation instructions in § 9.3 wherever applicable, it is best to surround the inclinometer casing in crest with graded material as per procedure described below. A typical installation is illustrated in figure 10-1.

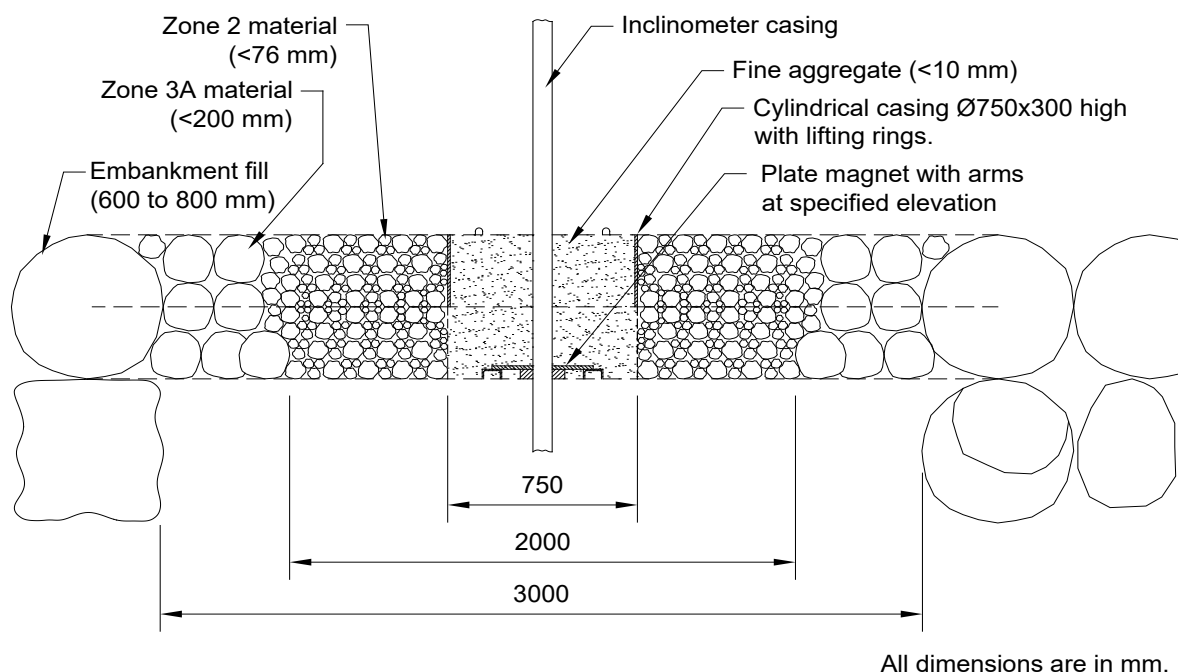


Figure 10-1 Typical details of fill around casing

- Because of graded fill requirement around inclinometer casings, the installation will have to proceed after every 1.2 metres of main fill is in place and compacted. A pit of approximately 3 metres diameter at the bottom shall be left during the fill procedure.

- d. Place a mild steel cylinder (typically 750 mm diameter x 300 mm high) formwork centred on the inclinometer location mark. Locate bottom cap of casing at the location mark and centre the cylinder around the casing.
- e. Stand the bottom casing vertically on the capped end with the help of guy ropes to be held by three persons each.
- f. Orient casing vertically with help of guy ropes. Use plumb bob for this purpose. It is good practice to grout fix lower end of casing. Effort should be made to install casing within 1° from the vertical.
- g. Carry on fill operation in lifts of approximately 300 mm height. Build next layer only when preceding layer has been properly compacted. Only use hand held compactors for compaction around casings (figure 10-2). Four fill layers will raise fill height by around 1.2 m that is just sufficient to hold the inclinometer tubing vertically in places.
- h. The sheet steel cylinder is used to place and compact the sand and fine aggregate fill immediately around the inclinometer casing. After the layer is compacted the cylinder is raised up and out of the finished layer in preparation for the next layer. The other two graded zones shown in the figure 10-1 outside the 750 mm diameter cylinder can be carefully hand placed and compacted. It is easier if the outer layer of fill material is placed first followed by the inner layer of fill material.
- i. Remove guy ropes only after casing is two-thirds embedded in fill.
- j. Once fill level reaches top of casing, add another length of casing using a telescopic coupling.
- k. Suitably extended telescopic coupling to accommodate expected settlement/rebound. Hold casing in extended condition with help of two pop rivets riveted diametrically opposite telescopic joints. Grease the telescopic joint or cover with plastic as a bond breaker for the back fill. Waterproof sealing tape is used to extend and keep the telescopic section to the required opening. Proper sealing by the waterproof tape is also necessary to prevent intrusion of backfill materials inside the casing.



Casing with telescopic coupling installed in rockfill section of dam, supported by guy ropes.



Casing with telescopic coupling being installed in rockfill section of dam, using hand help compactor

Figure 10-2

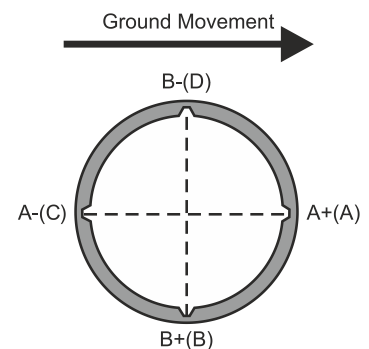
- I. Repeat above steps till all the access casings and telescopic couplings are assembled. This of course will have to go along with the filling of the embankment. Insure that joints are riveted and waterproof sealing tape is properly applied.

CAUTION: Groove alignment must be maintained throughout the installation process, to avoid inducing torsion in the casing thereby causing spiralling of the grooves.

- m. Flush the inside of the casing with water during assembly and after it is fully assembled. This is to prevent any back fill or dirt from sticking on to the grooves in the casing and impairing the movement of the probe. Always keep the top end of the casing covered with the top cap.

10.4 Marking of grooves (sign convention)

Mark the casing grooves as 'A','B','C' and 'D' with a permanent ink marker pen. If the uppermost torpedo wheel is pointed in the direction of the principal plane of movement, the casing groove pointing in this direction is marked as 'A'. Looking down the well, directions 'C','B' and 'D' are clockwise from 'A'.



10.5 Top protection

The top of the upper most casing should project around 150 mm above the ground level. Fix the protective top cap and lock it. When not taking readings, the gage well should be protected with the top cap and locked.

10.6 Fixing magnets (in fill – core & crest)

Settlement reading is normally required with lateral movement in embankment fill (earth/rockfill), as huge settlements are expected. Plate magnets are mounted on the inclinometer casing for monitoring settlements in fill.

1. Slide the datum magnet down the bottom most casing, that will grouted in the stable stratum, not susceptible to any settlement. Position the magnet at around 0.5 m height from the bottom of casing with 3 self-tapping screws as shown in figure 7-7 (in section 7) above.

NOTE: As the bottom of the access casing is located in the stable ground, the datum magnet becomes the benchmark or reference point. Locations of all other magnets are referred to this datum magnet to get their respective absolute settlement.

2. Wait till the level of clay/fill reaches the height/elevation of the plate magnet. Slide the plate magnet from the top to rest on the fill at required locations. Cover the magnet with fill material & compact to the same density as the surrounding fill (refer to figure 10-1). Repeat the process till all the magnets are installed.

Annexure 1 Importance of internal diameter of casing

The following calculation is based upon dimensions of Encardio-rite model EAN-26M inclinometer probe which has a diameter of 25 mm and a wheel spacing of 500 mm.

When embedded, the casing deforms with the lateral movement of earthworks or structures. Larger the diameter of the casing, lower is the chance of the inclinometer torpedo getting stuck into it due to deformation of the casing.

The minimum tolerable casing radius is achieved when a portion of the torpedo other than the wheels makes contact with the casing. The radius may be calculated approximately by the following formula:

$$R = \frac{(B_2^2 - B_1^2)}{(D_c - D_p)} \quad \text{equation 1}$$

where:

- R is the casing centerline radius
- B₁ is half the wheel spacing
- B₂ is the distance from the mid wheel base to the furthest extremity, typically the connector
- D_p is the torpedo diameter at the furthest extremity
- D_c is the inside diameter of the casing

Thus for the ER torpedo and 75.5 mm o.d. ER casing

- B₁ = 250 mm
- B₂ = 420 mm
- D_p = 25.0 mm at the connector
- D_c = 65.0 mm for the 75.5 o.d. casing
- R = 2.8 m as calculated by equation 1

Now take the example of a lower diameter casing

For a 61 mm o.d. casing (not sold or manufactured by E-R)

- D_c = 43.5 mm for the 61 mm o.d. casing
- R = 6.6 m as calculated by equation 1

It can be easily seen that the higher diameter casing can take much more deformation and lateral movement.

Obviously, in a real geotechnical situation, the casing is unlikely to deform at a constant radius, nor would it be likely to maintain a circular cross section. However, these calculations show a theoretical basis for predicting loss of use of a borehole due to deflection. Given the high cost of borehole re-drilling, the practice of using larger diameter casing in all cases where movement is likely, is strongly recommended.

NOTE: When using inclinometer casing with **IPI** or **IPIS**, user is advised to work our “R” based on gauge length (wheel spacing) specified. Lower the gauge length, better will be the results. It is recommended that a gauge length of more than 2 m should not be used.

